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A Numerical Analysis of Wind Flow within and above Idealised Modified Terraced House Canyon in Malaysia

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Abstract

This study examines the effects of surface roughness (modifications to existing structures) on wind flow. Idealised modified terraced house arrays were used in the study to represent the typical Malaysian terraced house urban-residential neighbourhood. The wind flow characteristics within and above an idealised modified terraced house canyon were investigated, with the idealised arrangement in a square and staggered layout, and the modifications installed 0.5*h* from the ground. The results indicate that the modifications affected the wind flow because of the smaller canyon width and the sheltering effect of the new obstacle.

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Keywords: numerical simulation; terraced house; surface roughness; velocity profile; wind flow

1. Introduction

Accelerated urbanization has resulted in the percentage of urban population in Malaysia increasing rapidly over the past 40 years, from 27% in 1970 to 71% in 2010 [1]. Urbanization has led to an increasing demand for new residential areas in Malaysia. Wind safety and wind comfort are important considerations in urban planning and building design, especially at the pedestrian level. The construction of a new building or modifications to existing buildings could alter the microclimate, i.e. the wind flow, of the surroundings, which could affect the comfort, health,

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and safety of the residents. For that reason, many international urban authorities currently request studies on wind safety and wind comfort at pedestrian level before granting building permits for the development of new buildings or new urban areas [2].

Numerous researchers have investigated the effects of various parameters on the wind flow characteristics around buildings [3,4,5,6]. However, most of these studies have focused on the wind flow around individual buildings or a cluster of buildings, rather than on the wind flow in larger areas, such as residential areas.

Several full-scale measurements have been conducted previously to study the wind flow characteristics within and above street canyons [7,8,9]. These measurements could provide ultimate real data; however, several weaknesses, i.e. uncontrollable meteorological conditions, complex building configurations, and limited measurement points make it difficult to generalize the collected data.

On the other hand, laboratory-scale measurements could be employed to resolve the above-mentioned measuring weaknesses. Several studies using laboratory-scale measurements have already been carried out to investigate street canyon flows [10,11,12]; however, as the spatial resolution in these studies was usually quite low, data from using such measurements are still inadequate.

In contrast with full- and laboratory-scale measurements, numerical simulation can provide a thorough visualization of the in-canyon wind flow at a high resolution. Two turbulence models are widely used in numerical simulation, namely, the Reynolds-averaged Navier-Stokes (RANS) and the Large-eddy simulation (LES). RANS has the advantage of reduced computational time compared with LES. However, RANS is generally less accurate in predicting unsteadiness in the wind fields in a street canyon. Therefore, the LES turbulence model has been used in several previous studies to investigate the wind structures and the behaviour of large-scale coherent structures above a canyon. Such a canyon is modelled by using a simple array of cubes to represent an urban street canyon [3,13]. Various other studies have used square bars to investigate the flow structures inside and above a canyon [14]. However, there is still a lack of studies on the wind flow characteristics within and above a modified canyon.

This study is designed to clarify the effects of modification to houses (the attachment of small roughness to original houses) on the wind flow characteristics, which could lead to urban-residential climate changes. In most urban-residential areas in Malaysia, the majority of existing housing units are terraced houses (42%, as of 2010) [1]. Therefore, simplified terraced house models were chosen to represent these urban residential areas. It was assumed that the terraced house estates all had the same layout style, and several rows of simplified rectangular blocks were used to represent this layout. Numerical simulation was implemented in this study instead of full-scale measurement or wind-tunnel experiments because of the effectiveness of this method in predicting the wind flow distribution [15]. Applying a cyclic boundary condition in the terraced house models created an unlimited spread of built-up area [15] and reduced the domain and calculation time of the simulation. Two types of modifications were tested in this study to investigate the effects of different arrangements of small roughness on wind flow characteristics within and above the canyon. The size of the simplified terraced house and modification models was based on the published guidelines and standards in the *Manual Guideline and Selangor State Planning Standards* (2010) [16]. The results of this study should be a significant addition to the body of knowledge on the wind flow characteristics within and above an urban-residential area, after modifications to the structures had taken place.

Nomenclature

h	standard building height
U	spatially averaged streamwise velocity
U_{2h}	reference velocity
$u'w'$	Reynolds shear stress
z	vertical distance
$_{ho}$	house original
$_{hm}$	house model
$_{ro}$	renovation original
$_{rm}$	renovation model